Sensitivity

Climate stressors and disturbance regimes

Salamanders, including the Pacific giant salamander (*Dicamptodon tenebrosus*), are very sensitive to shifts in water temperature and moisture availability because these factors affect growth and development, survivorship, and susceptibility to disease.

- **Increasing levels of UV-B radiation** caused by decreases in stratospheric ozone and climate warming can cause lowered hatch rates, increased rates of hatchling deformity, decreased growth rates and immune dysfunction, and may lead to individual mortality (Cockell & Blaustein 2013; Blaustein et al. 2003).
- **Altered hydrological cycles, reduced snowpack, and earlier timing of snowmelt** may disrupt salamander phenology and developmental timing, causing stress and mortality (McMenamin et al. 2008).
- **Increasing air temperatures combined with decreasing precipitation** may affect the physiology, behavior, and ecology of salamanders, in large part due to their highly permeable skin, which is dependent on available moisture to function as an osmoregulatory and respiratory organ (Hillyard 1999). These changes may also drive loss or degradation of sensitive habitats, such as ephemeral ponds, which may cause salamander population declines or local extirpations (Blaustein et al. 2010).
- **Warmer water temperatures** reduce the concentration of dissolved oxygen in aquatic habitats, which may delay development and/or hatching, or could cause premature hatching (Blaustein et al. 2010).
- **Increased disease risk** is likely with increased water temperatures and decreased flow in rivers and streams. Chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobatidis*, has contributed to world-wide amphibian declines and has severely affected several species in California, including the California slender salamander (*Batrachoseps attenuatus*; Sette et al. 2015).
- **Increased wildfire frequency and/or severity** may kill adult salamanders in terrestrial environments and reduce prey and woody material used as shelter. Fires temporarily reduce moist terrestrial conditions needed for salamander survival (e.g., by opening canopy), but do help increase water yield for streams over the long-term by reducing forest density. Post-fire debris flows can eliminate instream and riparian habitat and kill young salamanders, but do help create long-term habitat structural diversity (Norgaard et al. 2016).

Non-climate stressors

Non-climate stressors that reduce habitat and microhabitat quality and connectivity and reduce streamflow may exacerbate the impacts of climate change on salamanders.

- **Timber harvest, residential and commercial development, and transportation corridor development** increases habitat fragmentation, which can prevent successful dispersal of juveniles across habitats, and result in substantial reductions in post-metamorphic survival, reducing population connectivity and viability (Cushman 2006). These land use activities also reduce canopy cover and causes shifts in vegetation composition, which may alter temperature and moisture levels and affect the accumulation and decomposition of leaf litter that provides important microhabitat for salamanders (Blaustein et al. 2010). Additionally, the Pacific giant salamander has lower levels of genetic variation in areas of recent clearcuts, which suggests reduced population sizes and densities, and the possibility of local extirpation (Curtis & Taylor 2004).
- **Introduced species of non-native fish** (mainly trout and salmon) prey on eggs and larval salamanders, reducing survival (Ryan et al. 2014).
- **Roads, highways, and trails** present a road-kill hazard, as well as introduce pollutants and contaminants to nearby aquatic habitats through runoff (Sagar et al. 2007).
- **Culverts and associated water diversions** can disrupt natural habitat by modifying water velocity and the hydrological processes affecting sediment transport and bedload (Sagar et al. 2007).

Draft vulnerability briefing for the Northern California Climate Adaptation Project.
Fire suppression practices can increase the risk of high-severity fire in riparian habitats by increasing forest density, with potential negative impacts on salamanders. Fire retardant chemicals used to suppress fires can also cause salamander mortality (Norgaard et al. 2016).

**Dependence on habitat and prey/forage species**
Salamanders are dependent on habitats with sufficient moisture to hydrate their highly permeable skin and adequate leaf litter for use as foraging grounds and microhabitat; these habitat characteristics are in decline due to effects of climate change and other stressors (Blaustein et al. 2010). Salamanders often occur in riparian or moist forests and near cold creeks, rivers, streams, lakes, and ponds (Norgaard et al. 2016). Larval Pacific giant salamanders are aquatic, are often the dominant vertebrate predators in high gradient streams throughout their range, and like other larval salamanders feed on aquatic invertebrates (Taylor et al. 1988), whose population densities may be affected by changes in temperature, precipitation, and hydrology (Leeper & Taylor 1998).

**Adaptive Capacity**

**Geographic extent**
The range of the Pacific giant salamander is from northwestern California to southwestern British Columbia (Taylor et al. 1988).

**Overall health and functional integrity**
Amphibians worldwide are suffering from population declines, range reductions, and extinctions (Blaustein et al. 2010), which will likely be perpetuated under changing climate conditions.

**Dispersal ability**
The dispersal ability of salamanders is severely limited by clear cutting and habitat fragmentation, as they will not disperse any appreciable distance across non-forested habitat (Cushman 2006). Pacific giant salamanders tend to remain closer to streams, spend more time in subterranean refuges, and have smaller home ranges in areas of clearcuts than in forested habitat (Johnston & Frid 2002).

**Life history diversity**
Salamanders display a high diversity of life histories across species. The Pacific giant salamander is born in water with filamentous external gills, and may transform into terrestrial salamanders that breathe with lungs, but more frequently retain their gills and continue to live in the water (Trumbo et al. 2013).

**Ability to resist/recover from stressors**
As ectotherms, salamanders are particularly vulnerable to changes in temperature and precipitation (McMenamin et al. 2008). Salamanders are unable to disperse to alternate habitats across landscapes fragmented by human activity, decreasing their ability to avoid stressors and increasing their susceptibility to mortality (Cushman et al. 2006).

**Literature Cited**


